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(54) **METHOD OF USING MULTIPLE DEVELOPING MEMBERS IN A SINGLE-COMPONENT DEVELOPING SYSTEM**

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G03G 15/08 (2006.01)

(52) **U.S. Cl.** **399/266**; 399/55; 399/285; 399/290

(58) **Field of Classification Search** 399/279, 399/285, 265, 266, 290, 291, 53, 55
See application file for complete search history.

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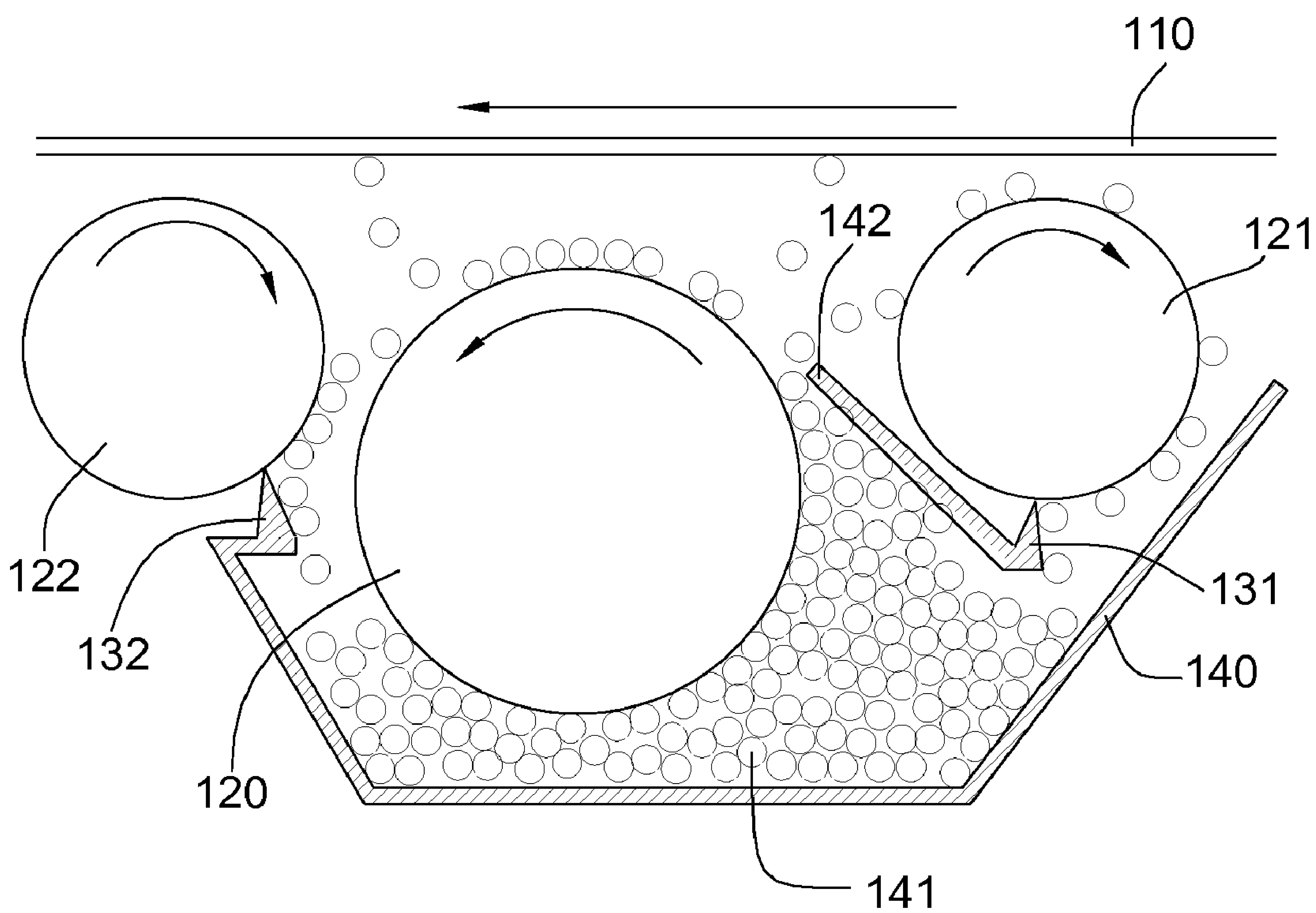
(57) **ABSTRACT**

The present invention is directed to a non-contact, single-component developing system for electrophotographic devices that enables high speed, high quality development and color development without an accumulator, or some other intermediate transfer member by employing a plurality of ancillary developing members operating in tandem with a toner-carrying member to facilitate toner detachment from the toner-carrying member. The developing system of the present invention utilizes high electrostatic forces to enable toner jump without AC voltages and exploits toner adhesion forces adhering toner particles to a surface (e.g., a latent image-bearing member) to facilitate high speed development.

16 Claims, 7 Drawing Sheets



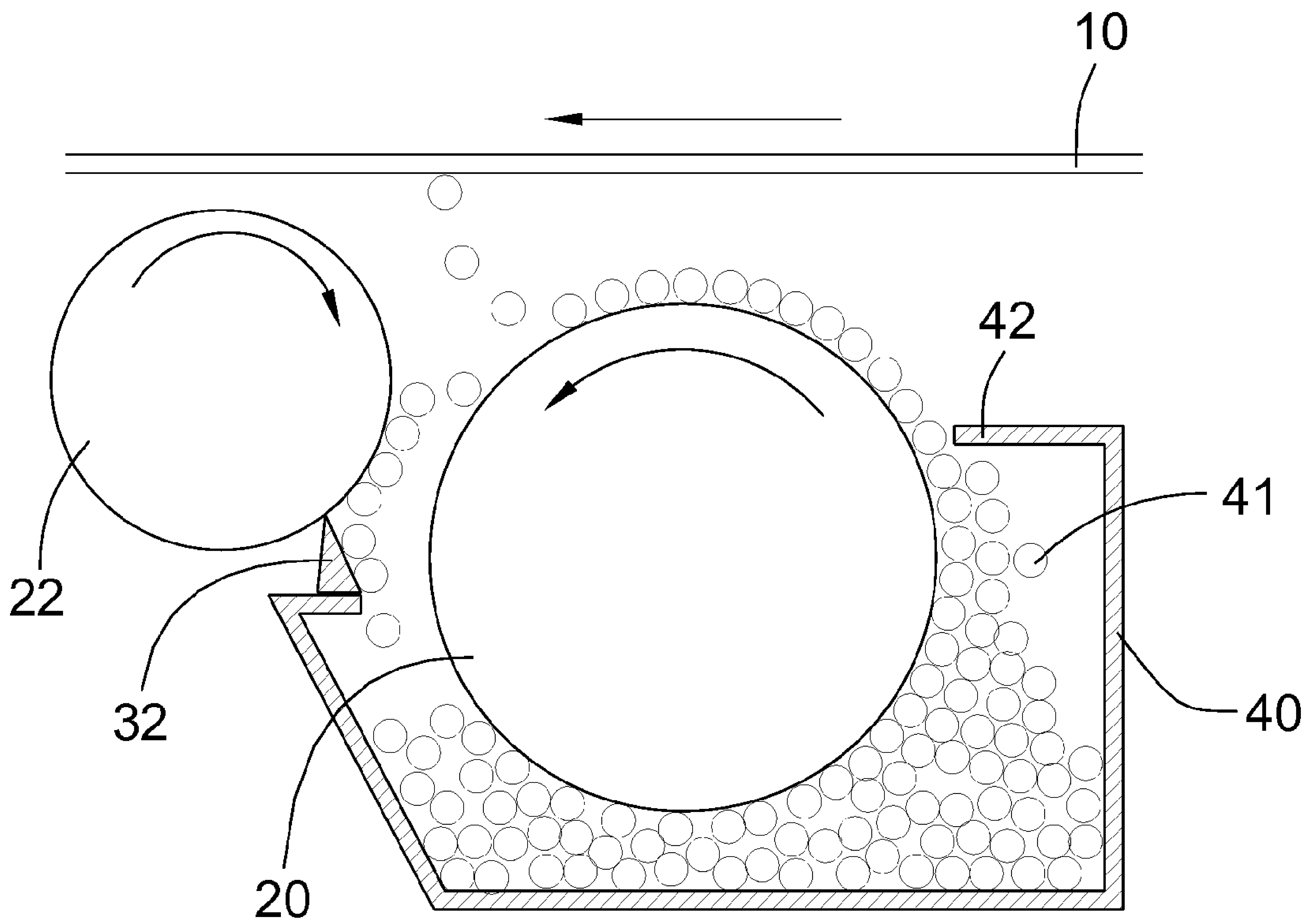


FIG. 1

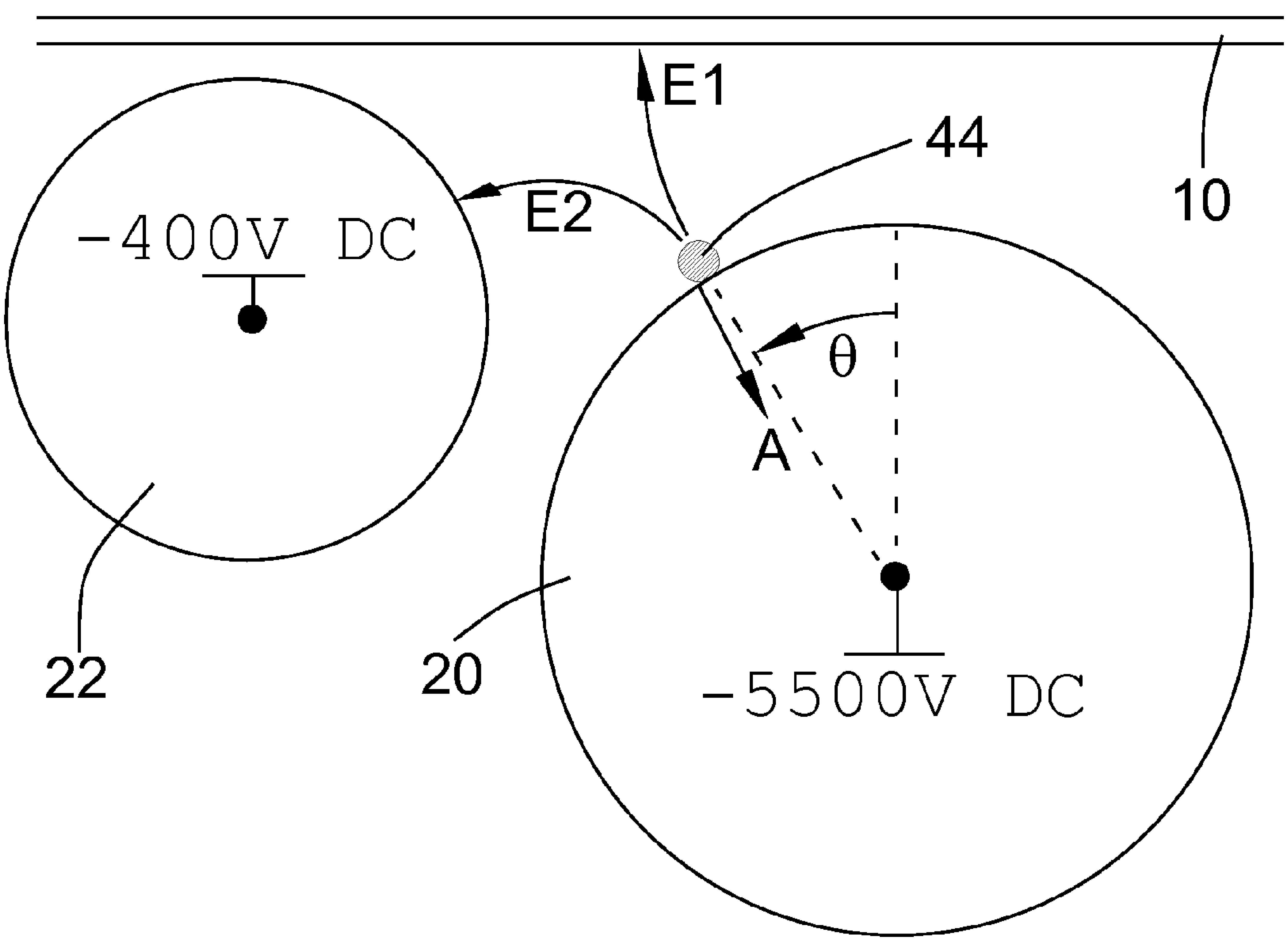


FIG. 2

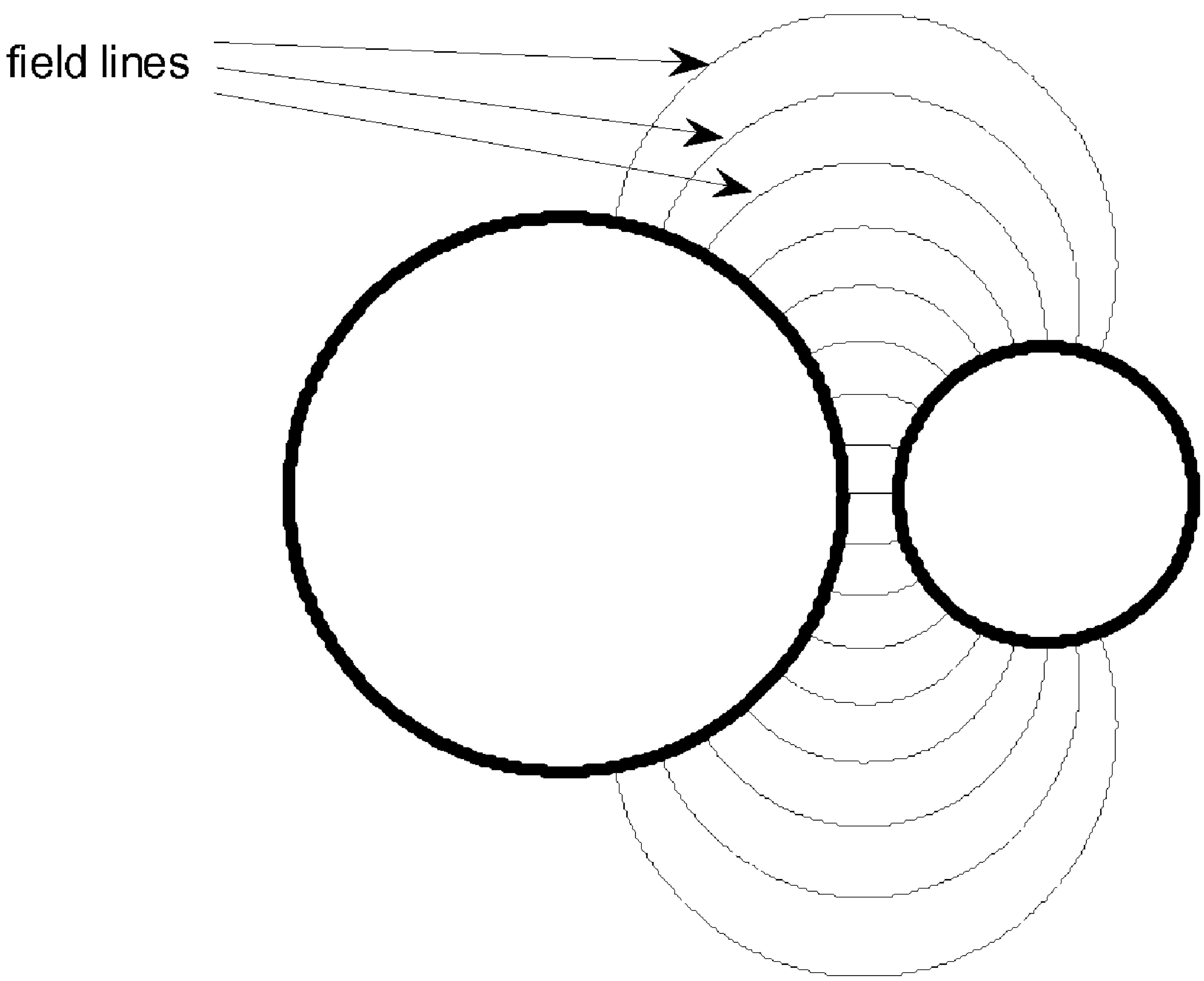


FIG. 3

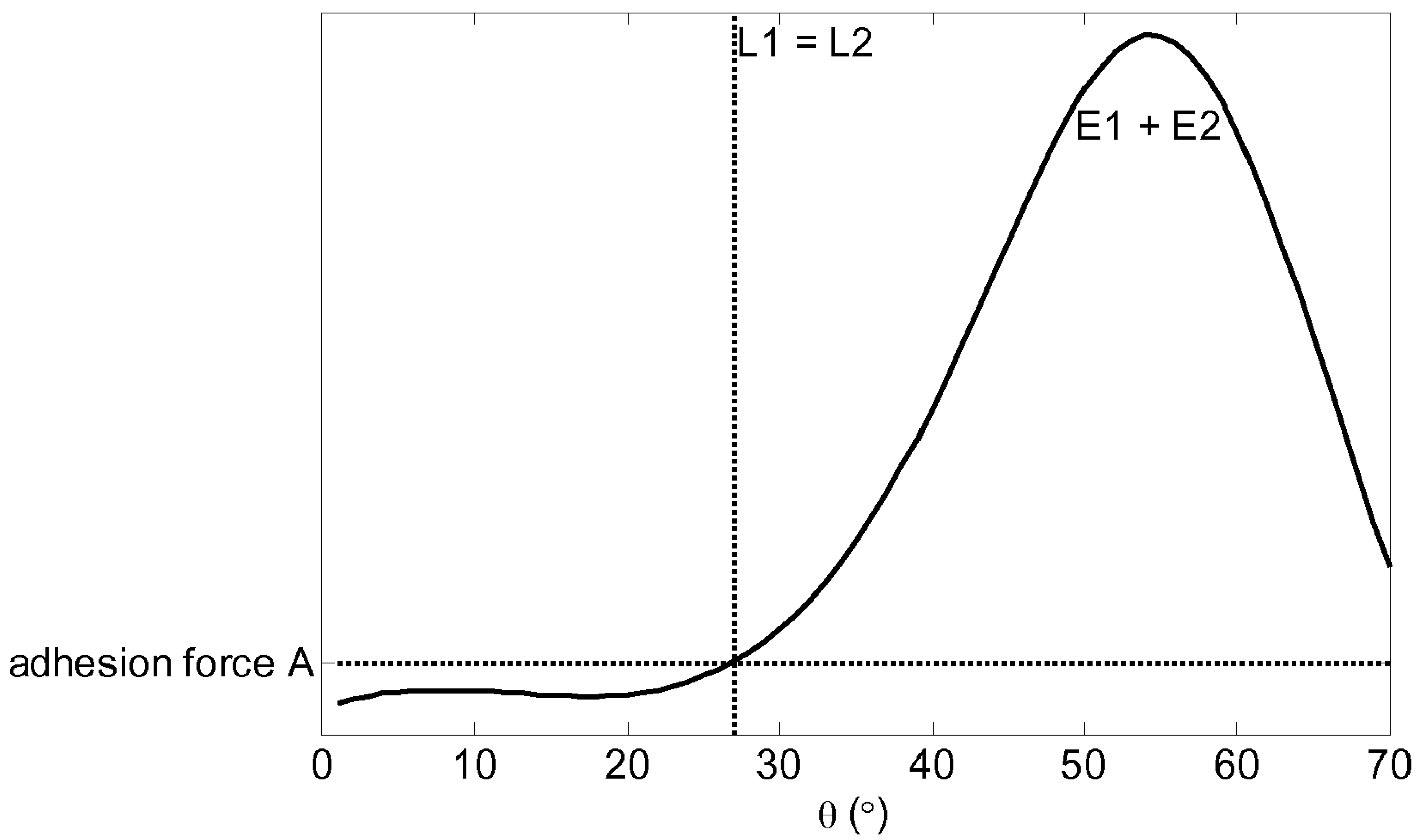


FIG. 4

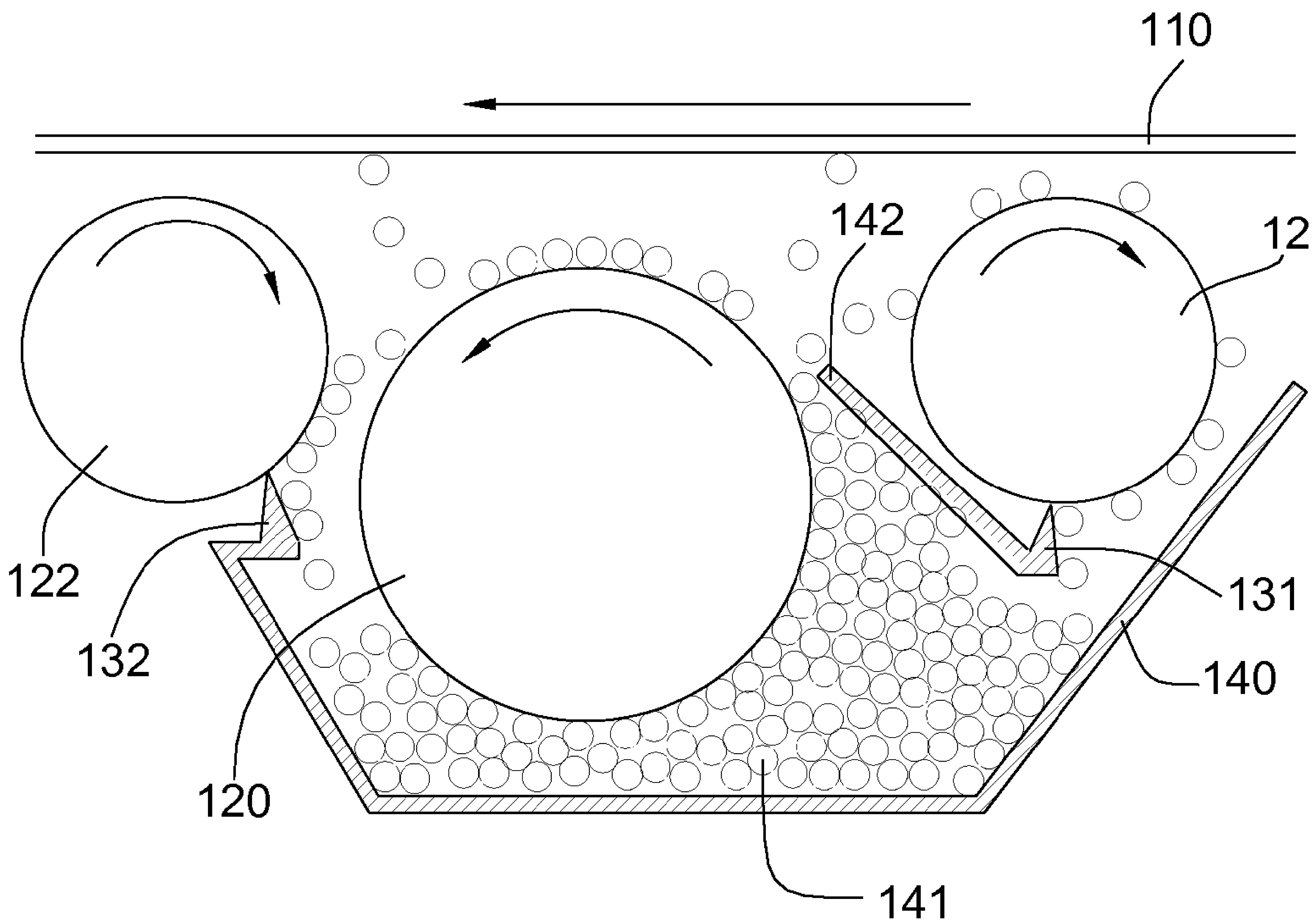


FIG. 5

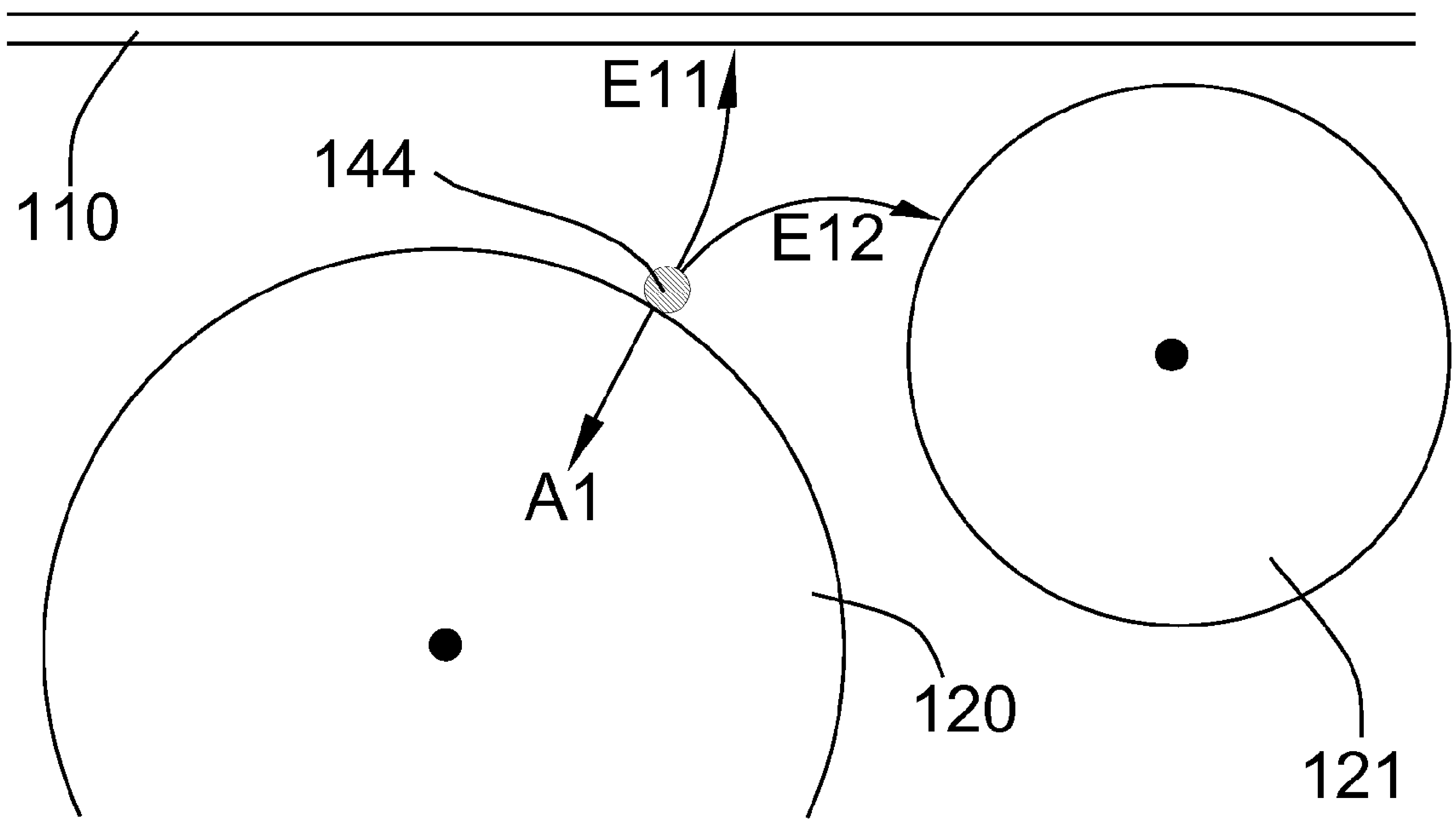
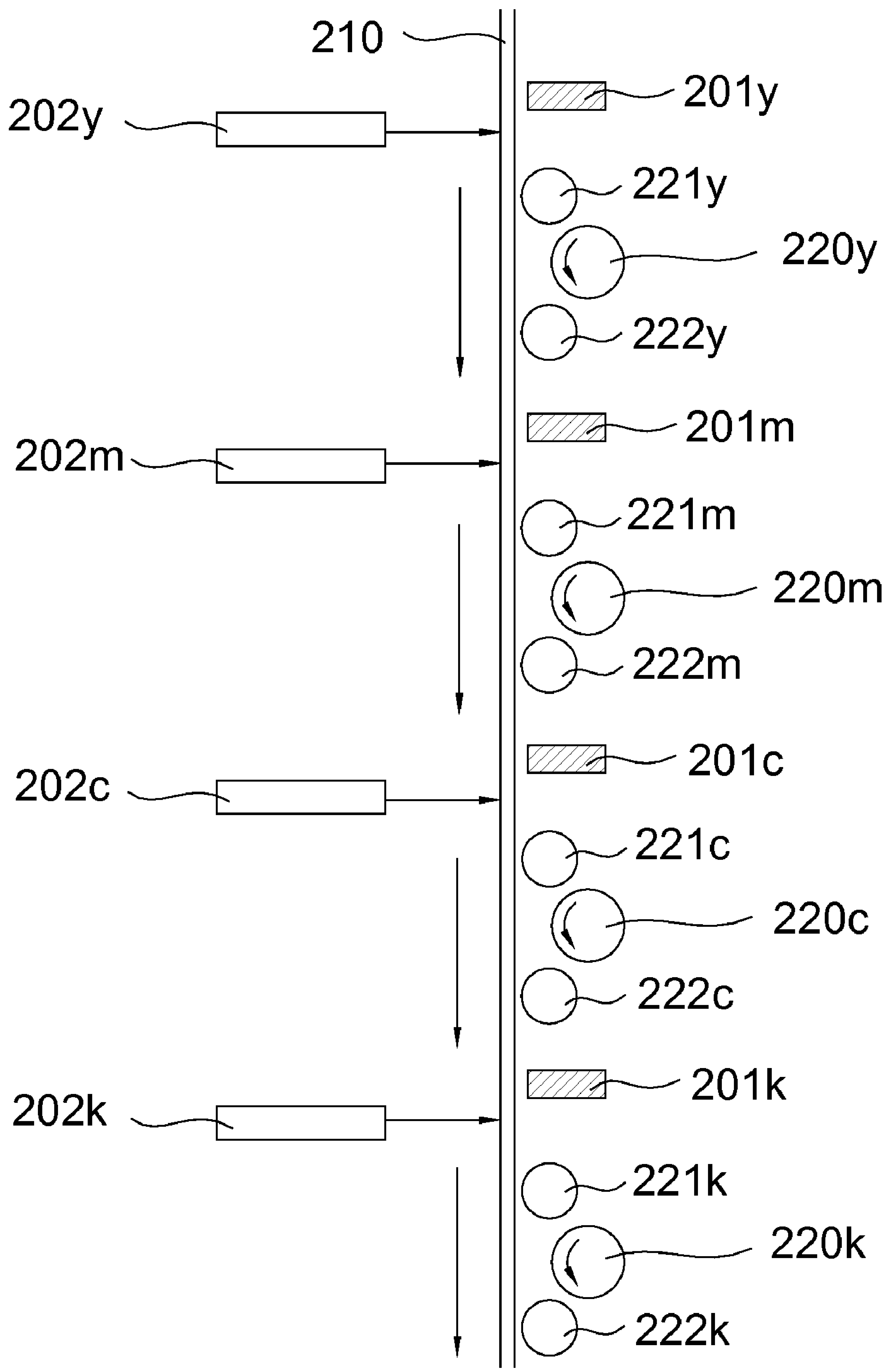


FIG. 6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202y
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222c
202k
201k
221k
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222k

FIG. 7

METHOD OF USING MULTIPLE DEVELOPING MEMBERS IN A SINGLE-COMPONENT DEVELOPING SYSTEM

FIELD OF THE INVENTION

The present invention is directed generally to electrophotography, more particularly, to a non-contact, single-component developing system employing a plurality of ancillary developing members that enables high speed development of electrostatic images and facilitates the consistent reproduction of high quality output images.

BACKGROUND OF THE INVENTION

Electrophotographic imaging process employs a charge-retentive, photosensitive member to form an electrostatic latent image. The latent image is rendered visible by depositing toner particles thereon. The developed particles are then transferred from the latent image to a transfer material such as paper. The resultant powder image deposited on the transfer material is permanently affixed thereto by applying heat and/or pressure, or with solvent vapor.

Color electrophotographic development is achieved by sequentially repeating the development process described above for each color and superimposing the developed images onto one another.

Various developing methods for visualizing electrostatic images are known in the art. One method is known as "non-contact" or "gap-jumping" development, wherein a thin layer of toner particles adhering to a toner-carrying member separated by a "gap" from a latent image-bearing member is brought into the developing region between the toner-carrying member and the latent image-bearing member. A high voltage associated with the latent image on the latent image-bearing member exerts electrostatic forces that direct the toner particles towards the latent image. The electrostatic forces are often of insufficient magnitude to overcome the adhesion forces holding the toner particles in the thin layer on the toner-carrying member. It has been proposed to apply a high AC bias voltage to the developing region in order to overcome the adhesion forces. The AC voltage is of sufficient magnitude to peel the toner particles from the toner-carrying member and allow the toner particles to "jump" the gap between the toner-carrying member and the latent image-bearing member. The toner particles land on the latent image-bearing member to form a developed image. The reciprocal nature of an AC voltage in turn frees the toner particles adhering to the latent image-bearing member from the latent image-bearing member and exerts electrostatic forces that direct the toner particles back to the toner-carrying member. This process is repeated until the latent image area moves far away from the developing region and the toner particles settle on the latent image area. The use of an AC bias has adversary effects on print speed because the rate at which the toner particles oscillate in the developing region (i.e., AC frequency) must be significantly greater than the rate at which the latent image on the latent image-bearing member moves (i.e., the surface moving speed of the latent image-bearing member) and an increase in AC frequency often results in undesirable artifacts such as poor reproducibility of thin character and line images. Furthermore, color developing in the presence of an AC bias requires one latent image-bearing member for each color and an accumulator or some other intermediate transfer member that stores each developed "tone" image, increasing the complexity and cost of the electrophotographic imaging system.

It has been proposed to eliminate the need for AC bias and/or an accumulator using various methods (e.g., by effectively reducing the impact of toner adhesion forces on the development process and thereby facilitating toner jump, or by increasing the thickness of a latent image-bearing member and thereby increasing the potential difference between latent image areas and non-image areas).

It has also been proposed to employ multiple developing rollers to enable high speed, high quality development. However, developing rollers were either sequentially activated, or disposed to repetitively perform substantially the same functions of a single developing roller.

In order to enable high speed development and eliminate the need for an accumulator while fully taking advantage of toner adhesion forces without employing rollers that perform substantially identical functions, a novel developing method capable of further improving the performance and functionality of a single developing roller by employing ancillary developing members is expected.

BRIEF SUMMARY OF THE INVENTION

The present invention is directed to a non-contact, single-component developing system for electrophotographic devices that enables high speed, high quality development and color development without an accumulator, or some other intermediate transfer member by employing a plurality of ancillary developing members such as rotating drums or belts operating in tandem with a toner-carrying member to facilitate toner detachment from the toner-carrying member. The term "non-contact" used in the present invention means that the toner-carrying member is separated by a prescribed gap from the toner-receiving surface of a latent image-bearing member and does not necessarily mean that none of the ancillary developing members are disposed in contact with the latent image-bearing member.

The gap between the toner-carrying member and the latent image-bearing member is larger than a typical gap in a non-contact, single-component developing system and consequently the toner-carrying member is biased (DC only) to a potential that is larger in magnitude (but not large enough to cause arcing between the toner-carrying member and the latent image-bearing member) than a typical DC bias used in such a developing system. The DC bias applied between the toner-carrying member and the latent image-bearing member produces an electrostatic force of insufficient magnitude to overcome toner adhesion forces that adhere toner particles to the toner-carrying member.

The ancillary developing members are strategically disposed and biased to exert supplemental electrostatic forces on toner particles adhering to the toner-carrying member that tend to free the toner particles from the toner-carrying member and direct the toner particles towards the ancillary developing members. Toner particles that are freed from the toner-carrying member due to the combined electrostatic forces fly towards either the latent image-bearing member, or the ancillary developing members, depending on the strengths of the electrostatic forces. The toner particles travel towards the latent image-bearing member if the electrostatic forces exerted in the gap between the toner-carrying member and the latent image-bearing member are of greater magnitude than those exerted in the gap between the toner-carrying member and the ancillary developing members. Conversely, the toner particles travel towards the ancillary developing members if the electrostatic forces exerted in the gap between the toner-carrying member and the latent image-bearing member are of smaller magnitude than those exerted in the gap between the toner-carrying member and the ancillary developing members. Thus, toner particles develop on latent image areas only. When non-image areas on the latent image-bearing member are brought into the region between the toner-carrying member and the ancillary developing members, toner particles either remain on the toner-carrying member, or fly towards and arrive at the ancillary developing members. Therefore, the developing system of the present invention provides improved image quality and eliminates background development. Furthermore, the combined electrostatic forces are sufficient to overcome toner adhesion forces and cause toner jump without the use of AC bias. This enables color development without an accumulator or some other intermediate transfer member.

Once toner particles arrive at the surface of the latent image-bearing member, or the ancillary developing members, the toner particles remain on the destination surface and do not return to the toner-carrying member. Electrostatic forces exerted on the toner particles do not direct the toner particles back to the toner-carrying member. Furthermore, adhesion forces adhering the toner particles to the destination surface cause the toner particles to remain on the destination surface. This advantageous exploitation of adhesion forces and the use of high electrostatic forces to facilitate toner jump enable high speed development that is less sensitive to the surface moving speed of the latent image-bearing member.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a schematic of a non-contact, single-component developing system of the present invention that employs a single ancillary developing member.

FIG. **2** is a schematic illustrating the forces acting upon a toner particle during the development process.

FIG. **3** is a graph showing electric field lines between two cylindrical surfaces.

FIG. **4** is a graph showing the combined electrostatic force as a function of toner-carrying member rotation angle.

FIG. **5** is a schematic of a non-contact, single-component developing system of the present invention that employs two ancillary developing members.

FIG. **6** is a schematic illustrating the forces acting upon a toner particle during the first stage of the development process.

FIG. **7** is a schematic of a non-contact, single-component color developing system in accordance with the present invention that employs two ancillary developing members for each color.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

The non-contact, single-component developing system of the present invention enables high-speed development of an electrostatic image and facilitates consistent high quality image reproduction. More particularly, the developing system of the present invention utilizes high electrostatic forces without AC voltages and exploits adhesion forces that adhere toner particles to a toner-carrying member by employing a plurality of ancillary developing members such as rotating drums or belts, whose electrostatic force contributions enable toner particles of various sizes and charges to jump from the toner-carrying member to a latent image-bearing member. Detached toner particles are directed and move in outward directions (i.e., from the toner-carrying member to the latent image-bearing member or the ancillary developing members), causing toner particles to jump the gap only once. Once toner particles are freed from the toner-carrying member, they move rapidly due to the electrostatic forces acting on the toner particles that are of high enough magnitude to overcome toner adhesion forces. This rapid one-way trip to the destination surface allows the developing system to be less sensitive to print speed (i.e., surface moving speed).

Referring in detail to the figures, FIG. **1** shows a non-contact, single-component developing system in accordance with the present invention. The developing system includes a latent image-bearing member **10** such as a photosensitive drum or belt. An electrostatic latent image is formed on the surface of the latent image-bearing member **10** by a latent image forming mechanism or latent image forming means (not shown) and the surface of the latent image-bearing member **10** moves in the direction of an indicated arrow.

The developing system also includes a toner container **40**, a toner-carrying member **20**, and an ancillary developing member **22**. Hereinafter, the ancillary developing member **22** will be referred to as the "post-developer." A metering blade **42** as a toner layer regulating means operates to create a thin layer of toner particles **41** and to charge the toner particles **41** on the toner-carrying member **20**. As described in detail below, toner particles that are freed from the toner-carrying member **20** arrive at the latent image-bearing member **10** or the post-developer **22**. A cleaning blade **32** removes toner particles transferred to the post-developer **22** and the removed toner particles are collected into the toner container **40**.

The surface moving speeds (i.e., circumferential speeds) of the toner-carrying member **20** and the post-developer **22** are substantially identical to the surface moving speed of the latent image-bearing member **10**.

The post-developer **22** and the toner-carrying member **20** are disposed to form a gap between the latent image-bearing member **10** and the toner-carrying member **20**, a gap between the latent image-bearing member **10** and the post-developer, **22** and a gap between the toner-carrying member **20** and the post-developer **22**. Furthermore, the post-developer **22** and the toner-carrying member **20** are disposed in such a way that an electrostatic latent image recorded on the latent image-bearing member **10** passes the toner-carrying member **20** first and then the post-developer **22**. The gap between the latent image-bearing member **10** and the toner-carrying member **20** is in the range from about 800 to 2,500 microns, preferably about 1600 microns. The gap between the latent image-bearing member **10** and the post-developer **22** is in the range from 20 to 300 microns, preferably about 100 microns. The gap between the toner-carrying member **20** and the post-developer **22** is in the range from about 500 to 2,000 microns, preferably about 800 microns.

The surface of the latent image-bearing member **10** is initially uniformly charged by a charging mechanism or charging means (not shown) to preferably about −700 V (DC). After exposure of the latent image-bearing member **10** to light to form an electrostatic latent image, the potential of the latent image-bearing member **10** is reduced to approximately −50 V (DC).

A DC bias voltage is applied between the toner-carrying member **20** and the latent image-bearing member **10**. The toner-carrying member **20** is biased to a potential in the range of approximately −2,000 to −8,000 V (DC), preferably about −4,500 to −6,000 V (DC), desirably about −5,500 V (DC). The post-developer **22** is biased to a potential between the image area potential and the non-image area potential (i.e., between −700 V and −50 V (DC)), preferably about −400 V (DC). Alternatively, an AC bias voltage having a peak-to-peak value of preferably about 100 V and a frequency of preferably about 5,000 Hz may be applied between the post-developer **22** and the latent image-bearing member **10** in superposition with the DC bias applied therebetween in order to facilitate toner detachment from the toner-carrying member **20**.

Although negative DC voltages are used above, it will be understood that positive voltages can also be used in accordance with the present invention by recording positive charge images on the latent image-bearing member **10** and reversing the polarities of DC bias voltages.

As shown in FIG. **2**, as the toner-carrying member **20** carries the toner near the latent image-bearing member **10** and subsequently towards the post-developer **22**, a toner particle **44** experiences electrostatic forces E**1** and E**2** that tend to free the toner particle **44** from the toner-carrying member **20** and an adhesion force A that adheres the toner particle **44** to the toner-carrying member **20**. The electrostatic force E**1** directed towards the latent image-bearing member **10** results from the potential difference between the toner-carrying member **20** and the latent image-bearing member **10**, and is of insufficient magnitude to overcome the adhesion force A even in the region where the distance between the latent image-bearing member **10** and the toner-carrying member **20** is the shortest (i.e., when E**1** is the strongest). Thus, no toner develops until the toner reaches a region that is substantially close to the post-developer **22**. The electrostatic force E**2** results from the potential difference between the toner-carrying member **20** and the post-developer **22** and directs the toner particle **44** towards the post-developer **22**. For the toner particle **44** to be caused to leave the surface of the toner-carrying member **20**, the combined electrostatic force (i.e., E**1**+E**2**) must be sufficient to overcome the adhesion force A.

In general, force is directly proportional to electric field and charge. The electrostatic forces E**1** and E**2**, and the adhesion force A, therefore, may be expressed in terms of electric field. The electrostatic forces E**1** and E**2** are then approximately

$$E1 = \frac{V_{dev} - V_{PC}}{L1} \text{ and } E2 = \frac{V_{dev} - V_{post}}{L2},$$

where V_{dev} is the DC bias applied to the toner-carrying member **20**, V_{PC} is the surface potential of the latent image-bearing member **10**, V_{post} is the DC bias applied to the post-developer **22**, L**1** is the field line length between the toner-carrying member **20** and the latent image-bearing member **10**, and L**2** is the field line length between the toner-carrying member **20** and the post-developer **22**. A field line between two surfaces represents a passage along which a charged particle will travel, as illustrated in FIG. **3**.

FIG. **4** shows an example plot of the combined electrostatic force E**1**+E**2** as a function of rotation angle θ of the toner-carrying member **20** (see FIG. **2**) where V_{PC}=−50 V (DC). The combined electrostatic force E**1**+E**2** is of sufficient magnitude to overcome the adhesion force A when the rotation angle θ is approximately 27° in FIG. **4**. Incidentally, the field line lengths L**1** and L**2** are approximately equal when θ=27°. But the line representing L**1**=L**2** may shift left and right and/or the curve E**1**+E**2** may shift up and down depending on the values of the parameters discussed above such as the DC bias voltages.

According to the example illustrated in FIG. **4**, the toner particle **44** is freed from the toner-carrying member **20** when the rotation angle θ is 27° due to the combined electrostatic force E**1**+E**2** that exceeds the adhesion force A and flies towards either the latent image-bearing member **10**, or the post-developer **22**, depending on the strengths of the electrostatic forces E**1** and E**2**. The toner particle **44** travels towards the latent image-bearing member **10** if the surface potential of the latent image-bearing member **10** is approximately −50 V (DC) (i.e., image area) because the potential difference between the latent image-bearing member **10** and the toner-carrying member **20** is greater than that between the toner-carrying member **20** and the post-developer **22** (i.e., E**1**>E**2** because L**1**=L**2**, see the equations above). Conversely, the toner particle **44** travels towards the post-developer **22** if the electrostatic force E**2** exerted in the gap area between the toner-carrying member **20** and the post-developer **22** is of greater magnitude than the electrostatic force E**1** exerted in the gap area between the latent image-bearing member **10** and the toner-carrying member **20**. Since E**2**>E**1** when the surface potential of the latent image-bearing member **10** is approximately −700 V (DC), a non-image area does not attract and receive the toner particle **44**.

In addition to the electrostatic forces E**1** and E**2**, the potential difference between the post-developer **22** and the latent image-bearing member **10** creates an additional electrostatic force that directs the toner particle **44** towards the latent image-bearing member **10** if the surface potential of the latent image-bearing member **10** is approximately −50 V (DC), or towards the post-developer **22** if the surface potential of the latent image-bearing member **10** is approximately −700 V (DC). Therefore, the DC bias applied to the post-developer **22** further ensures that toner particles develop on latent image areas only. When non-image areas are brought between the toner-carrying member **20** and the post-developer **22**, toner particles simply fly towards and arrive at the post-developer **22**.

From FIG. **4**, a toner particle that exhibits a stronger adhesion force is detached from the toner-carrying member **20** when the rotation angle θ is greater than 27° and the particle is subject to the identical developing mechanism as described above. That is, the particle will develop on an image area recorded on the latent image-bearing member **10**, or land on the post-developer **22**, but will not be attracted to a non-image area on the latent image-bearing member **10**. Thus, the developing system of the present invention is capable of consistently producing high quality output images.

Once toner particles leave the toner-carrying member **20**, due to the high electrostatic forces exerted on those particles, they tend to travel rapidly and quickly arrive at the surface of the latent image-bearing member **10**, or the post-developer **22**. Adhesion forces that adhere the transferred toner particles to the destination surface and electrostatic forces exerted on the transferred toner particles tend to hold the toner particles to the destination surface. Therefore, the developing system of the present invention does not allow toner particles that leave the toner-carrying member **20** and arrive at a destination surface to return to the toner-carrying member **20**. High electrostatic and adhesion forces cause the transferred toner particles to remain on the destination surface. This advantageous exploitation of adhesion forces and rapid toner travel to the destination surface enable high speed development of electrostatic images that is less sensitive to an increase in the surface moving speed of the latent image-bearing member **10**.

The developing system of the present invention also eliminates wrong-signed toner development. Wrong-signed toner development causes various undesirable artifacts such as foggy background (i.e., non-image area development). Because of the high negative DC bias applied to the toner-carrying member **20**, wrong-signed toner particles (i.e., positively charged particles) remain on the surface of the toner-carrying member **20**, completely eliminating the possibility of developing those positively charged particles.

FIG. **5** shows another preferred embodiment of the present invention. The non-contact, single-component developing system shown in FIG. **5** includes a latent image-bearing member **110** such as a photosensitive drum or belt, a toner-carrying member **120**, and two ancillary developing members **121** and **122**. Hereinafter, the first ancillary developing member **121** will be referred to as the "pre-developer," and the second ancillary developing member **122** as the "post-developer."

The developing system also includes a toner container **140**, a metering blade **142**, and two cleaning blades **131** and **132**. The metering blade **142** operates to create a thin layer of toner particles **141** and to charge the toner particles **141** on the toner-carrying member **120** from the toner container **140**. As described in detail below, toner particles that are freed from the toner-carrying member **120** develop on the latent image-bearing member **110**, or land on the pre-developer **121** or the post-developer **122**. The cleaning blades **131** and **132** remove toner particles transferred to the pre-developer **121** and post-developer **122**, respectively, and the removed toner particles are collected into the toner container **140**.

The surface moving speeds (i.e., circumferential speeds) of the toner-carrying member **120**, and the post-developer **122** are substantially identical to the surface moving speed of the latent image-bearing member **110**. The surface moving speed of the pre-developer **121**, however, is significantly greater than that of the latent image-bearing member **110**, and is preferably about twice the surface moving speed of the latent image-bearing member **110**.

The latent image-bearing member **110**, the pre-developer **121**, the post-developer **122**, and the toner-carrying member **120** are disposed to form a gap between the latent image-bearing member **110** and the toner-carrying member **120**, a gap between the latent image-bearing member **110** and the pre-developer **121**, a gap between the toner-carrying member **120** and the pre-developer **121**, a gap between the latent image-bearing member **110** and the post-developer **122**, and a gap between the toner-carrying member **120** and the post-developer **122**. Furthermore, the pre-developer **121**, the post-developer **122**, and the toner-carrying member **120** are disposed in such a way that an electrostatic latent image recorded on the latent image-bearing member **110** passes the pre-developer **121** first, then passes the toner-carrying member **120**, and lastly passes the post-developer **122**. Preferably, the gap between the latent image-bearing member **110** and the toner-carrying member **120** is approximately 1,600 microns; the gap between the latent image-bearing member **110** and the pre-developer **121** is approximately 100 microns; the gap between the toner-carrying member **120** and the pre-developer **121** is approximately 1,500 microns; the gap between the latent image-bearing member **110** and the post-developer **122** is approximately 100 microns; and the gap between the toner-carrying member **120** and the post-developer **122** is approximately 800 microns.

The surface of the latent image-bearing member **110** is initially uniformly charged by a charging mechanism or charging means (not shown) to preferably about −700 V (DC). Subsequently, an electrostatic latent image is formed on the surface of the latent image-bearing member **110** by a latent image forming mechanism or latent image forming means (not shown). After exposure of the latent image-bearing member **110** to light, the potential of the latent image-bearing member **110** is reduced to approximately −50 V (DC).

A DC bias voltage is applied between the toner-carrying member **120** and the latent image-bearing member **110**. The toner-carrying member **120** is preferably biased to a potential in the range of approximately −4,500 to −6,000 V (DC). The pre-developer **121** and the post-developer **122** are biased to potentials between the image area potential and the non-image area potential (i.e., between −700 V and −50 V (DC). Preferably, the potential of the pre-developer **121** and the post-developer **122** is approximately −400 V (DC).

As the toner-carrying member **120** carries the toner **141** towards the pre-developer **121**, toner particles that are adhered to the toner-carrying member **120** by relatively weak adhesion forces are freed from the toner-carrying member **120** and transferred to the pre-developer **121**. The pre-developer **121** carries the transferred toner particles into the gap between the latent image-bearing member **110** and the pre-developer **121**. The difference between the bias voltage on the pre-developer **121** (−400 V) and the image area potential (−50 V) on the latent image-bearing member **110** may exert a force of sufficient magnitude on the transferred toner particles to overcome the weak adhesion forces and cause the toner particles to jump the gap between the pre-developer **121** and the latent image-bearing member **110**. The difference between the bias voltage on the pre-developer **121** (−400 V) and the non-image area potential (−700 V) exerts a force on the transferred toner particles that directs the transferred toner particles towards the pre-developer **121** and hence causes the transferred toner particles to remain on the pre-developer **121**. Thus, the transferred toner particles develop on image areas on the latent image-bearing member **110**, but not on non-image areas. Alternatively, provided that only a negligible amount of toner development occurs in the gap between the latent image-bearing member **110** and the pre-developer **121**, the pre-developer **121** may rotate in the opposite direction of an indicated arrow in FIG. **5**, in which case toner particles that are transferred to the pre-developer **121** will not be carried into the gap between the latent image-bearing member **110** and the pre-developer **121** and will be brought back towards to toner container **140** and scraped off into the toner container **140**.

Particles that are not transferred to the pre-developer **121** are brought towards the latent image-bearing member **110**. As shown in FIG. **6**, a toner particle **144** that is exposed to both the pre-developer **121** and the latent image-bearing member **110** experiences electrostatic forces E**11** and E**12** that tend to free the toner particle **144** from the toner-carrying member **120** and an adhesion force A**1** that adheres the toner particle **144** to the toner-carrying member **120**. The electrostatic force E**11** directed towards the latent image-bearing member results from the potential difference between the toner-carrying member **120** and the latent image-bearing member **110**. The electrostatic force E**12** results from the potential difference between the toner-carrying member **120** and the pre-developer **121** and directs the toner particle **144** towards the pre-developer **121**. If the combined electrostatic force (i.e., E**11**+E**12**) is not sufficient to overcome the adhesion force A**1**, the toner particle **144** remains on the toner-carrying member **120** and subsequently the toner-carrying member **120** carries the toner particle **144** towards the post-developer **122**. On the other hand, If the combined electrostatic force (i.e., E**11**+E**12**) is sufficient to overcome the adhesion force A**1**, the toner particle **144** is caused to leave the surface of the toner-carrying member **120**, and the strengths of the electrostatic forces E**11** and E**12** determine its destination surface. That is, if the electrostatic force E**11** is greater than E**12**, the particle **144** flies towards the latent image-bearing member **110**, else it flies towards the pre-developer **121**.

In addition to the electrostatic forces described above, the high surface moving speed of the pre-developer **121** creates a windage that directs the toner particle **144** towards the latent image-bearing member **110**, facilitating the development of the particle **144** when the electrostatic force E**12** is slightly greater than the electrostatic force E**11** and the surface potential of the latent image-bearing member **110** is approximately −50 V.

In essence, the pre-developer **121** develops toner particles that are held by relatively weak adhesion forces (e.g., improperly charged particles and particles with small contact areas), or transfers those particles to the pre-developer **121**. This eliminates the possibility of undesirable development when toner particles are carried into the region between the toner-carrying member **120** and the latent image-bearing member **110**, and hence removes undesirable artifacts such as foggy background (i.e., non-image area development).

Particles that are brought near the post-developer **122** are subject to the same developing mechanism described in the previous embodiment shown in FIG. **1**. When the sum of the electrostatic forces resulting from the potential difference between the toner-carrying member **120** and the latent image-bearing member **110** and from the potential difference between the toner-carrying member **120** and the post-developer **122** is sufficient to overcome the adhesion forces that adhere the toner particles to the toner-carrying member **120**, the toner particles are caused to leave the surface of the toner-carrying member **120**. The toner particles travel towards the latent image-bearing member **110** if the surface potential of the latent image-bearing member **110** is approximately −50 V (i.e., image area). Conversely, the toner particles travel towards the post-developer **122** if the surface potential of the latent image-bearing member **110** is approximately −700 V (i.e., non-image area). Also, the potential difference between the post-developer **122** and the latent image-bearing member **110** creates an additional electrostatic force that directs the toner particles towards the latent image-bearing member **110** if the surface potential of the latent image-bearing member **110** is approximately −50 V, or towards the post-developer **122** if the surface potential of the latent image-bearing member **110** is approximately −700 V. Therefore, the DC bias applied to the post-developer **122** further ensures that toner particles develop on latent image areas only. When non-image areas are brought between the toner-carrying member **120** and the post-developer **122**, the toner particles simply fly towards and arrive at the post-developer **122**.

The two ancillary developing members **121** and **122** operate in tandem with the toner-carrying member **120** to develop toner particles on image areas only. The developing system improves print quality and reproducibility by employing a double-pass development scheme. During each pass, the combined electrostatic forces are sufficient to cause toner particles to jump from the toner-carrying member **120** without the use of an AC bias. This enables color development without an accumulator or some other intermediate transfer member.

FIG. **7** shows a non-contact, single-component color developing system in accordance with the present invention. The color developing system includes a latent image-bearing member **210** such as a photosensitive drum or belt, four toner-carrying members **220***y*, **220***m*, **220***c*, and **220***k*, four pre-developers **221***y*, **221***m*, **221***c*, and **221***k*, and four post-developers **222***y*, **222***m*, **222***c*, and **222***k*.

The first toner-carrying member **220***y* carries yellow toner (not shown) into the first developing region defined by the latent image-bearing member **210**, the first pre-developer **221***y*, the first toner-carrying member **220***y*, and the first post-developer **222***y*; the second toner-carrying member **220***m* carries magenta toner (not shown) into the second developing region defined by the latent image-bearing member **210**, the second pre-developer **221***m*, the second toner-carrying member **220***m*, and the second post-developer **222***m*; the third toner-carrying member **220***c* carries cyan toner (not shown) into the third developing region defined by the latent image-bearing member **210**, the third pre-developer **221***c*, the third toner-carrying member **220***c*, and the third post-developer **222***c*; and the fourth toner-carrying member **220***k* carries black toner (not shown) into the fourth developing region defined by the latent image-bearing member **210**, the fourth pre-developer **221***k*, the fourth toner-carrying member **220***k*, and the fourth post-developer **222***k*.

The pre-developer **221***y* and the post-developer **222***y* operate in tandem with the toner-carrying member **220***y* to develop the yellow toner on the latent image-bearing member **210**; the pre-developer **221***m* and the post-developer **222***m* operate in tandem with the toner-carrying member **220***m* to develop the magenta toner on the latent image-bearing member **210**; the pre-developer **221***c* and the post-developer **222***c* operate in tandem with the toner-carrying member **220***c* to develop the cyan toner on the latent image-bearing member **210**; and the pre-developer **221***k* and the post-developer **222***k* operate in tandem with the toner-carrying member **220***k* to develop the black toner on the latent image-bearing member **210**.

The four toner-carrying members **220***y*, **220***m*, **220***c*, and **220***k*, the four pre-developers **221***y*, **221***m*, **221***c*, and **221***k*, and the four post-developers **222***y*, **222***m*, **222***c*, and **222***k* are substantially similarly DC biased as in the previous embodiment shown in FIG. **5**.

The color developing system also includes four charging means **201***y*, **201***m*, **201***c*, and **201***k*, and four latent image forming mechanisms or latent image forming means **202***y*, **202***m*, **202***c*, and **202***k* such as LED arrays.

The color developing system operates as follows. The first charging means **201***y* uniformly charges the latent image-bearing member **210** to approximately −700 V (DC). Subsequently, an electrostatic latent image is formed on the surface of the latent image-bearing member **210** by the first latent image forming mechanism **202***y*. The potential of the exposed portions of the latent image-bearing member **210** is reduced to approximately −50 V (DC). As the latent image on the latent image-bearing member **210** is brought into the first developing region, the yellow toner particles develop on the image areas as described in the previous embodiment shown in FIG. **5**. The second charging means **201***m* then uniformly charges the latent image-bearing member **210** again to approximately −700 V (DC) and the second latent image forming mechanism **202***m* shines light onto specific portions of the latent image-bearing member **210** that require the inclusion of the color magenta. The potential of those exposed portions of the latent image-bearing member **210** is reduced to approximately −50 V (DC) if no toner is deposited thereon, and to approximately −200 V (DC) if toner particles are already deposited thereon. Thus, the potential difference between light exposed portions of the latent image-bearing member **210** and the second toner-carrying member **220***m* is reduced by approximately 150 V (DC) when magenta toner particles are to be deposited on top of yellow toner particles. However, the reduction in potential difference is of insignificant magnitude when compared against the high DC bias applied between the second toner-carrying member **220***m* and the latent image-bearing member **210**. In fact, the reduction in potential difference (150 V) corresponds to less than 4% of the DC bias applied between the toner-carrying member **220***m* and the latent image-bearing member **210** and hence the corresponding reduction in electrostatic forces from the reduction in potential difference has little impact on the development of magenta toner particles. After magenta toner particles are developed, the process is repeated for the two remaining colors.

Once toner particles land on the latent image-bearing member **210**, or on toner particles already deposited on the latent image-bearing member **210**, electrostatic forces exerted on the toner particles and adhesion forces adhering the toner particles to the latent image-bearing member **210** and to each other cause the toner particles to remain on the latent image-bearing member **210**. This advantageous exploitation of electrostatic forces and adhesion forces enables efficient, reliable accumulation of different color toner particles on the latent image-bearing member **210**, resulting in consistent production of high quality output images.

The foregoing description of the various embodiments and principles of the inventions have been presented for the purposes of illustration and description. It is not intended to be exhaustive or to limit the invention to the precise forms disclosed. Many alternatives, modifications, and variations will be apparent to those skilled in the art. Moreover, although various inventive concepts have been presented, such aspects need not to be utilized in combination, and various combinations of inventive aspects are possible in light of the various embodiments provided above. Accordingly, the above description is intended to embrace all possible alternatives, modifications, combinations and variations that have been discussed or suggest herein, as well as all others that fall within the principles, spirit and broad scope of the invention as defined by the claims.

What is claimed is:

1. A non-contact, single-component developing system comprising:

a latent image-bearing member capable of having an electrostatic latent image recorded thereon,

a toner-carrying member for carrying a layer of a toner thereon,

a first plurality of ancillary developing members,

a second plurality of ancillary developing members and

toner removing means for removing the toner from the first and second plurality of ancillary developing members, wherein

a DC bias voltage is applied between the toner-carrying member and the latent image-bearing member;

a DC bias voltage is applied between at least one of the first plurality of ancillary developing members and the latent image-bearing member;

a DC bias voltage is applied between at least one of the second plurality of ancillary developing members and the latent image-bearing member;

the latent image-bearing member and the toner-carrying member are disposed to form a prescribed gap therebetween;

the latent image-bearing member passes the first plurality of ancillary developing members prior to passing the toner-carrying member;

the latent image-bearing member passes the second plurality of ancillary developing members after passing the toner-carrying member;

the surface of at least one of the first plurality of ancillary developing members moves at a constant velocity;

the first plurality of ancillary developing members facilitate toner jump from the toner-carrying member by producing electrostatic forces that direct the toner away from the toner-carrying member;

the surface of at least one of the second plurality of ancillary developing members moves at a constant velocity;

the second plurality of ancillary developing members facilitate toner jump from the toner-carrying member by producing electrostatic forces that direct the toner away from the toner-carrying member;

the toner jumps from the toner-carrying member and selectively lands on either the latent image-bearing member, at least one of the first plurality of ancillary developing members, or at least one of the second plurality of ancillary developing members;

the toner on at least one of the first plurality of ancillary developing members and at least one of the second plurality of ancillary developing members is removed by the toner removing means.

2. The developing system of claim **1** wherein the second plurality of ancillary developing members are removed and the first plurality of ancillary developing members comprise of an ancillary developing member disposed to form a gap between the latent image-bearing member and the ancillary developing member and a gap between the toner-carrying member and the ancillary developing member.

3. The developing system of claim **1** wherein the first plurality of ancillary developing members are removed and the second plurality of ancillary developing members comprise of an ancillary developing member disposed to form a gap between the latent image-bearing member and the ancillary developing member and a gap between the toner-carrying member and the ancillary developing member.

4. The developing system of claim **1** wherein the first plurality of ancillary developing members comprise of a first ancillary developing member; and the second plurality of ancillary developing members comprise of a second ancillary developing member.

5. The developing system of claim **4** wherein the first ancillary developing member is disposed to form a gap between the latent image-bearing member and the first ancillary developing member and a gap between the toner-carrying member and the first ancillary developing member; and the second ancillary developing member is disposed to form a gap between the latent image-bearing member and the second ancillary developing member and a gap between the toner-carrying member and the second ancillary developing member.

6. The developing system of claim **5** wherein the gap between the latent image-bearing member and the toner-carrying member is 600 to 2,500 μm; the gap between the first ancillary developing member and the toner-carrying member is 500 to 2,000 μm; the gap between the second ancillary developing member and the toner-carrying member is 500 to 2,000 μm; the gap between the latent image-bearing member and the first ancillary developing member is 20 to 250 μm; and the gap between the latent image-bearing member and the second ancillary developing member is 20 to 250 μm.

7. The developing system of claim **6** wherein the DC bias voltage applied between the toner-carrying member and the latent image-bearing member has a magnitude of 2,000 to 8,000 V; the DC bias voltage applied between the first ancillary developing member and the latent image-bearing member has a magnitude of 200 to 600 V; and the DC bias voltage applied between the second ancillary developing member and the latent image-bearing member has a magnitude of 200 to 600 V.

8. The developing system of claim **7** wherein the latent image-bearing member and the toner-carrying member rotate in the same direction at a position where the latent image-bearing member faces the toner-carrying member; the toner-carrying member and the second ancillary developing member rotate in the same direction at a position where the toner-carrying member faces the second ancillary developing member; and the toner-carrying member and the first ancillary developing member rotate in the same direction at a position where the toner-carrying member faces the first ancillary developing member.

9. The developing system of claim **8** wherein the surface moving speeds of the latent image-bearing member, the toner-carrying member, the first ancillary developing member, and the second ancillary developing member are substantially identical.

10. The developing system of claim **8** wherein the surface moving speeds of the latent image-bearing member, the toner-carrying member, and the second ancillary developing member are substantially identical; and the surface moving speed of the first ancillary developing member is substantially greater than that of the latent image-bearing member.

11. The developing system of claim **7** wherein an AC bias voltage having a peak-to-peak value of 50 to 200 V and a frequency of 2,000 to 10,000 Hz is applied between the first ancillary developing member and the latent image-bearing member in superposition with the DC bias voltage applied between the first ancillary developing member and the latent image-bearing member; and an AC bias voltage having a peak-to-peak value of 50 to 200 V and a frequency of 2,000 to 10,000 Hz is applied between the second ancillary developing member and the latent image-bearing member in superposition with the DC bias voltage applied between the second ancillary developing member and the latent image-bearing member.

12. The developing system of claim **4** comprising a light source and a charge source electrically coupled to the latent image-bearing member.

13. The developing system of claim **12** wherein the charge source comprises a plurality of charging members; the light source comprises a plurality of light emitting members; the toner-carrying member comprises a plurality of toner-carrying rollers; the first ancillary developing member comprises a first plurality of ancillary developing members; and the second ancillary developing member comprises a second plurality of ancillary developing members.

14. The developing system of claim **13** wherein the plurality of light emitting members comprise four light-emitting-diode arrays; the plurality of charging members comprise four charging members; the plurality of toner-carrying rollers comprise four toner-carrying rollers; the first plurality of ancillary developing members comprise four ancillary developing members; and the second plurality of ancillary developing members comprise four ancillary developing members.

15. The developing system of claim **14** wherein the toner comprises four color toners.

16. The developing system of claim **1** wherein the toner removing means comprises a plurality of blades disposed in close proximity to the first and the second plurality of ancillary developing members.

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